Spectroscopic Observations of Satellites at Kyung-Hee University in Korea

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ABSTRACT

We have been conducting spectroscopic observations of satellites in addition to photometric observations since last summer at the Kyung-Hee Optical Satellite Observation and Tracking Facility (KOSOTF). We began with observing slowly moving objects, such as geo-stationary satellites. We have undergone many trials and errors to succeed in the spectroscopic observations of these satellites. Necessary hardware and software being used are described. Observation and data acquisition techniques are also discussed although data analyses have not been completed. Future observing plans are presented for the spectroscopic and photometric observations of low altitude satellites.

INTRODUCTION

The KOSOTF at Kyung-Hee University (Fig. 1) has been set up and tested since July 20, 2000. Until recently, photometric observations have been conducted mainly for high orbital satellites. Since the color and pigment of satellites are usually different from each other, each satellite often has unique spectral characteristic. The extensive photometric observations of satellites have been previously made and the acquired data have been analyzed and reported in literature (e.g., Kissell and Vanderburgh, 1961-1962; 1971; and Crawford, et. al., 2000). However, spectroscopic observations have been seldom reported in literature. Recently, low-dispersion spectroscopic and photometric observations have been presented by Payne et. al. (2000). The observed satellites by Payne et al. appear to have distinctive spectra with broad spectral structures, although detailed spectral lines could not be seen.

The photometric observations at KOSOTF have been made by the Kyung-Hee Satellite Observation Research Team using a 30-inch telescope (Fig. 2) with UBVR filters and with an auto-guider (Fig. 2), which can lock slowly moving satellites. Spectroscopic observations have also been tested against geo-stationary satellites with the 30-inch telescope and with the auto-guider. We chose geo-stationary satellites, because they move slowly and therefore they are easy to accumulate sufficient light for the spectroscopic observations using a conventional telescope.

We are also planning to observe relatively low-altitude (4,000 km to 10,000 km) satellites using a 16-inch telescope with the GT-1100 mount, which is described in detail in the next section.

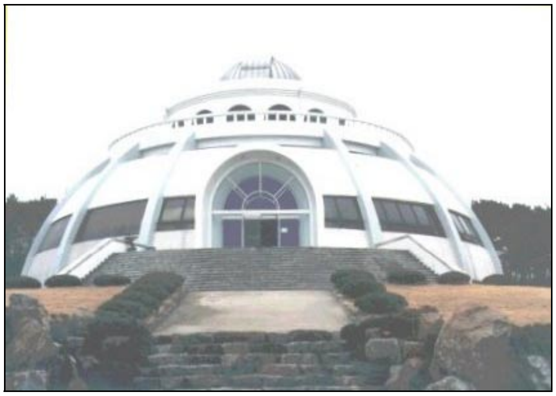

Figure 1: Kyung-Hee Astronomical Observatory

Figure 2: A 30-inch Ritchey-Chretién Telescope and an auto-guider attached to the main telescope.

CURRENT HARDWARE AND SOFTWARE FOR KOSOTF

Hardware

The main telescope is a 30-inch Ritchey-Chretién telescope on a half-fork type equatorial mount. The focal length to diameter ratio (f) of the primary mirror is 3, and that of the secondary mirror is 7. The resulting field-of-view (FOV) of the system is 15 x 17 arc-minutes. The CH250 1024 x 1024 CCD camera is used to take images.

The slit field in the spectrometer for the spectroscopic observations is very narrow for moving objects. In order to obtain the image of a satellite at the center of the slit of the spectrometer, Celestron 6-inch auto-guider (FOV: 25 x 25 arc-minutes) with SBIG ST-6 CCD (576 x 384) Camera is used.

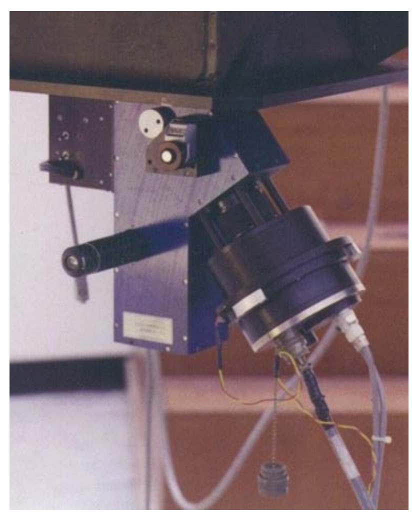

Figure 3: Spectrometer and CH-250 CCD Camera

An Optomechanics spectrometer (Fig. 3) is used with a grating of 600 groove/mm and a slit of 1.5 mm length and 50 micron width. The dispersion is 121 A/mm, the spectral resolution is 2.8 A, and the observable wavelength range is 3000-9000 A. The comparison sources used for wavelength calibrations are an Hg lamp for the wavelength range below 5800 A and a Ne lamp for above 5800 A.

Software

The Celestial Computing C-Sat software, which was especially designed for the Meade LX-200 Drive/Slew system, automatically scans space for objects in orbit over specific observing sites and allows observers to view the satellites directly through the telescope eyepiece. Because the telescopes at the KOSOTF were not designed to be compatible with the C-Sat software, the software is just used to find out locations of observable satellites on our site. The software is available with the Two-Line Element Sets (TLEs), which is supplied by the NORAD (North American Aerospace Defense Command). It is also used with the SGP4 and SDP4 satellite orbital perturbation's propagation models to make accurate predictions of satellite positions. The C-Sat's orbital search and scheduling routines are sufficiently accurate and easy to use at KOSOTF.

With the exception of the C-Sat software, other software used for satellite spectroscopic observations such as telescope control system and CCD operating system are the same as those used for usual stellar spectroscopic observations.

Tracking and Observing Techniques

After selecting a satellite observable at the KOSOTF site using the C-Sat program, the right ascension and declination of the satellite are fed into the telescope control system, and then the telescope mount is slewed to the satellite position. The FOV of the 30-inch telescope is 15 x 17 are-minutes, but the FOV of the slit through which we should confirm the identification of the satellite is very small. In order to ensure that the satellite is within the slit during the exposure time, the selected satellite is firstly tracked and identified by the auto-guider (FOV: 25 x 25 arc-minutes). Satellite motions can be easily distinguished from stellar motions. The identified satellite is then manually moved to the center of the field of the auto-guider, and the system is converted to the stare mode of the telescope. After the centering the satellite, the satellite has been re-tracked by the auto-guider during the exposure time. A perfect alignment of optical line between the main telescope and the auto-guider has been set -- The center of the auto-guider's field coincides with the center of the slit of the spectrometer at the 30-inch telescope. The geo-stationary satellites are usually very fainted: mostly below 10 magnitude, and therefore long exposures are usually required for obtaining meaningful spectra.

Another observing technique is currently being tried for the spectroscopic observations of satellites. This is to use the same spectrometer without the slit in order to obtain wider FOV through the spectrometer and to control the auto-guiding system more easily. However, this technique reduces the spectral resolution significantly, and detailed image processing is required to extract a satellite spectrum from the possible overlaps of stellar spectra.

FUTURE SYSTEM FOR KOSOTF

We are adding another satellite tracking system to the KOSOTF at Kyung-Hee University for the observations of low orbital satellites. The added and upgraded items are a 16-inch telescope with a GT-1100 robotic telescope mount, upgraded software, a spectrometer, a 6-inch auto-guider, and an ST-6/7E CCD camera, which are described in detail below.

Hardware

16-inch Telescope

A 16-inch Newtonian telescope has been modified to an open truss structure in order to reduce the weight to be compatible with the GT-1100 mount capacity. The 6-inch auto-guider is attached to the 16-inch telescope for the initial identification and tracking of satellites. The f-value is 4.1 and the FOV is 12.27 x 16.21 arc-minutes. After re-modeling, the total weight including the auto-guider, the spectrometer, and the CCD camera will be approximately 25kg. Figure 4 shows the design of the 16-inch open truss telescope and figure 5 shows a new dome.

GT-1100 Robotic Telescope Mount

This is a Software Bisque Paramount model with a German equatorial mount. The CASTOR (Canadian Automated Small Telescope for Orbital Research) is also using this mount for observing high orbital satellites (Earl et. al., 2000). The slew speed is known to be 3 degrees per second. However, it can be varied depending on the weight of the telescope and the altitude of observing objects. The slew speed of this mount will be rechecked against satellites, of which exact orbital elements are known. MKS 3000, a new DC-servo motor control system developed by Software Bisque will be installed when the mount needs faster slew speeds for tracking low orbital satellites.

16-inch Newtonian telescope on the GT-1100 mount

- Open truss structure (8 piece frame)
- 6 inch auto-guider with ST-6 CCD Camera,
- Spectrometer, ST-7E CCD Camera
- Total weight: 25kg
- Length: 171cm
- Height: 320cm
- Slew speed: max. 3 degrees

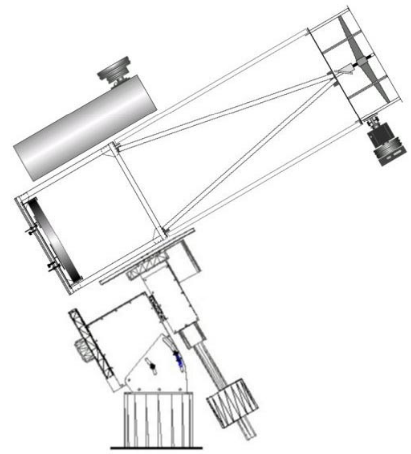

Figure 4: The 16-inch telescope and 6-inch auto-guider

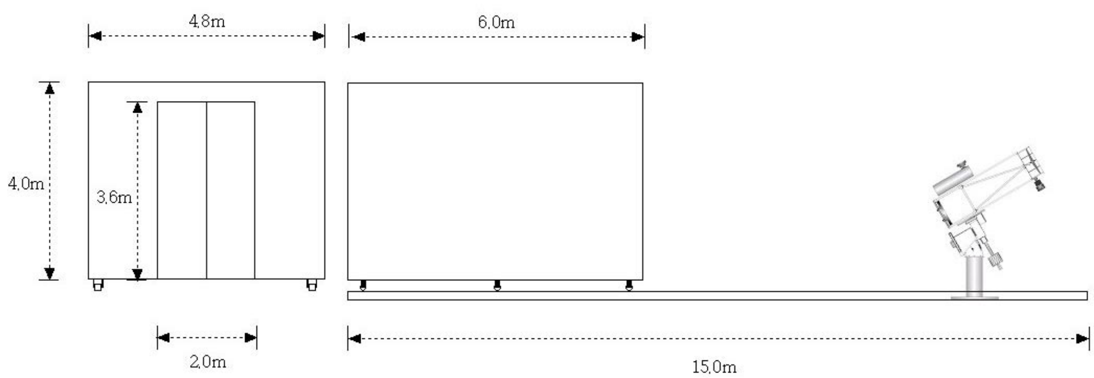

Figure 5: Sliding dome

ST-7E CCD Imaging Camera with Cooling-Optional

The quantum efficiency of the CCD is approximately 70%. The CCD camera (765·510 pixel) contains an adaptive optics (AO) system attached to the second CCD detector. The AO-7 adaptive optics is equipped with a high speed tip-tilt mirror for atmospheric correction in order to stabilize stellar images, to improve the core intensity of the images, and to enhance image resolution. Attached cooling optional will lower the temperature to –40 degree from ambient minimum temperatures.

Low Resolution Spectrometer

The spectrometer is designed to operate with an ST-7E/8 camera. Once the object is maneuvered into the slit, a self-guiding will hold the object on the slit. Thus, we are able to use long exposures for spectroscopic observations. The selected dispersion is 150 line/mm (4.3 A/pixel) and the resulting spectral resolution is 38 A. The wavelength range is from 3800 to 7500 A, and the spectral coverage per frame is 3200 A.

Software

The Sky Astronomical Software Package (Level □)

This is the most suitable software to the GT-1100 mount for astronomical or satellite tracking observations. The TLEs can be incorporated into the TheSky so that the user can easily see current satellite positions at a particular site. CCDSoft CCD Camera Software, T-Point Telescope Pointing Software, and Orchestrate Telescope Software are also used together as a package for an automated satellite tracking system.

C-Sat Satellite Tracking Software

This software package is to automatically scan the sky and to find satellites, and then to calculate their apparent positions. However, since it was designed for the LX-200, not compatible with our system, it will be used for obtaining the schedules of satellites.

CONCLUSIONS

We have conducted photometric and spectroscopic observations of satellites using the KOSOTF at Kyung-Hee University. We went through technical difficulties in pointing satellites within the slit of the spectrometer on the 30-inch telescope. However, our skill has been improved and we are now able to be pinpoint high orbital satellites for spectral observations. The spectral data are being analyzed and the results will be presented.

An augmented satellite tracking and observation facility with a 16-inch telescope is being constructed and tested, and preliminary results of the observations will be reported at the April conference. This facility will be mainly used for the photometric and spectroscopic observations of low orbital satellites.

We plan for continuous observations of low and high orbital satellites, and we will construct databases for spectral characteristics and classification of satellites orbiting over the Korean peninsula.

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